SPECIFICATION

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Freestanding Polymer MEMS Structures with Anti Stiction

Cross Reference to Related Applications

The present application claims priority from provisional application number 60/235,384, filed September 25, 2000.

Background of Invention

[0001] Integrated circuit materials and processing technologies enable forming multiple different kinds of MEMS sensors and actuators. MEMS fabrication may leverage off established processing technologies which are used to form semiconductor materials and structures. Importantly, this may also allow integration of micromechanical devices on the same chip that holds the electronics.

[0002] Polymer materials may be used as part of the MEMS structural materials, to obtain certain advantages. Biocompatibility of certain polymers may allow use of such structures in the biotechnology industry. Such polymers may also be formed at lower temperatures then other semiconductor devices, enabling operation over a lower temperature range.

[0003] In a polymer surface micromachined process, a specified polymer, such as Parylene, may be used as a structural layer. A sacrificial photoresist layer may hold Parylene in its desired location. Acetone may be used as a releasing agent. Although Parylene structures have been fabricated in this way, it may be difficult to form freestanding devices at a sufficiently small-scale.

Summary of Invention

[0004]

The present invention teaches anti stick technology to be used in MEMS formation. The anti stick technology may prevent a polymer cantilever from sticking to the substrate. In one embodiment, the anti stick technology includes a sacrificial layer that prevents sticking. In

another embodiment, either one or a number of legs extend from the polymer cantilever to the substrate and are freed after formation.

Brief Description of Drawings

[0005] These and other aspects will now be described in detail with reference to the accompanying drawings, wherein:figures 1A-1C show an embodiment using legs to prevents sticking;figures 2A-2C show using a special sacrificial anti stick layer; andfigures 3A-3C show a composite embodiment.

Detailed Description

[0006] The present inventors have found that the polymers used in this kind of process, such as Parylene, have a relatively small Young's modulus, e.g., around 4 Gpa. These materials may be fairly soft and pliable. After the sacrificial photoresist has dissolved, the surface tension of the acetone material may pull the relatively soft and pliable structural layer down toward the substrate. This may cause a so called stiction effect, in which the formed structure may stick to the substrate. This effect is a well-known problem in surface micromachining technology.

[0007] An attempt to solve this problem has used supercritical CO_2 drying to bypass the air-liquid interface and thus eliminate surface tension. However, the current inventors have found limited success with such structures and techniques. Theoretical calculations have predicted a limit of 84 microns for the longest cantilevered element that could be formed in this way.

[0008] The present application, and specifically the embodiments disclosed herein, define anti stiction techniques, used for fabricating relatively large freestanding polymer MEMS structures. The techniques described in this application may be formed based on gas phase etching such as bromine trifluoride and xenon difluoride etching of certain sacrificial materials. The sacrificial materials used may include silicon and titanium. The disclosed bromine trifluoride and xenon difluoride etching are technologies that provide relatively high etching selectivity of some silicon and titanium as compared with other polymer materials such as the Parylene and the photoresist. Gas phase etching may produce the advantage of avoiding the air-liquid interface force which may be otherwise involved in the final releasing process.

[0009] An embodiment shown in figure 1A-1C. The polymer structural layer, which may be Parylene, may be formed with structural posts therein to avoid the stiction effect.

[0010] Figure 1A shows an initial operation of preparing a substrate 100 which may be any

material, e.g., silicon. The substrate may have first areas 110, 111, 112 formed thereon. These areas may be patterned using any desired techniques, such as using sacrificial photoresist.

[0011] Photoresist areas 115, 116, 117 are formed to define the cavity area(s) underlying the cantilever 130. In this embodiment, the separations between the cavity parts are formed as 122, 123. For example, the area 122 is an area where no photoresist is formed. This may be located between two of the operative areas 115,116.

[0012] The overall structure is covered with polymer layer 125, which may be a Parylene layer. The polymer coats all of the exposed areas. This includes the areas 122 and 123, where the polymer will actually touch the substrate 100. Polymer also coats the photoresist areas 115,116,117. Figure 1B illustrate the result of using acetone to dissolve the photoresist. All the areas of photoresist such as 115 are removed by the acetone, leaving open spaces where the photoresist was previously located. This leaves the polymer structure 130 generally of the shape of an expanding cantilever having structural posts, effectively forming posts 131, 132 at specified locations along the length.

[0013] During the sacrificial photoresist dissolution, these legs act as posts, holding the polymer structure above the substrate, and preventing that structure from sticking to the substrate 100.

[0014] After the photoresist areas have been removed as shown in figure 1B, the device may be dried. A short gas phase etching using BrF_3 may then be applied, to remove substrate material 135 from areas under the posts 131. An undercut hole edge by BrF_3 may be around 35 microns in diameter and 4.4 microns in depth. This etching frees the polymer structure and enables it to move.

[0015] The final structure shown in figure 1C is therefore freed, with the freed areas being allowed to move freely.

[0016] An alternative embodiment is shown in figures 2A-2C, which uses an anti stick layer. Figure 2A shows initial operations of fabrication of the polymer structure with a composite sacrificial layer. The substrate 200 may be silicon as in previous embodiments. This substrate is covered over the area that will be under the cantilever, with an anti stiction layer 205. The anti stiction layer may be amorphous silicon, or titanium. Either of these materials can be evaporated or sputtered at low temperatures. This anti stiction layer 205 may be a sacrificial layer. However, thick layers of this material may not be practical because of possible increased

deposition time.

[0017] Hence, this may use a composite sacrificial layer, with a first portion of the layer 205 being an anti stiction layer 205, and a second portion 210 being formed of conventional photoresist.

[0018] As in the above embodiments, the sacrificial layers 210/205 are coated with a layer of polymer 215, which may be Parylene.

[0019] In figure 2B, the photoresist is dissolved away with acetone, leaving the second sacrificial layer 205. When the device is dried, the polymer structure 215 may stick down towards the substrate as shown in figure 2B.

[0020] In figure 2C, a short gas phase etching using BrF_3 and XeF_3 may operate to remove the second anti stiction layer 205. This can operate to free the polymer cantilever. Figure 2C shows how the final polymer structure 215 may be freed from the substrate.

[0021] While the above the embodiment has disclosed a composite layer of sacrificial material, it should be understood that a single layer of sacrificial material 205 may be used especially when only a thin cavity 216 under the cantilever is desired.

[0022] A composite embodiment is shown in figures 3A-3C. In this embodiment, both technologies, that is both the posts, and the anti stick layer are combined. Figure 3A shows fabrication of a polymer structure 300 with posts 302. Anti stick portions are located at least in portions under the posts. As an alternative, these portions may be located under the entire cantilever area.

[0023] Each post area is thus in contact with sacrificial layer 304. This sacrificial layer can be sacrificial amorphous silicon or titanium, or some other material, as above.

[0024] As in the figure 1 embodiment, figure 3B shows etching in acetone to remove the photoresist. This leaves the polymer structure 300 touching against the anti stick layer 304 at the area of the posts. In figure 3C, the anti stick layer 304 may be removed thus freeing the structures. The removal may use gas phase etching as described above.

[0025] The above technique has been used to form many freestanding structures of polymers. The specific polymers that are used may include Parylene. It has been found that this system may allow production of cantilevers, e.g., with about 150 microns between posts. Any beams that have widths larger than 100 microns may show stiction at the edges of the beams. Therefore, a

maximum distance between the center of the post to the edge of the beam may be 75 microns.

[0026] Although only a few embodiments have been disclosed in detail above, other modifications are possible. All such modifications are intended to be encompassed within the following claims, in which: